AMENDMENTS TO THE SPECIFICATION

Please replace the entire section of the specification following the title and preceding the figure descriptions with the following:

This invention relates to ~~radiation applicator~~microwave radiators and, in particular, to microwave ablation devices.

A known ~~radiation applicator~~microwave radiator, used for microwave ablation of tissue, comprises a microwave generator operatively coupled to an elongate waveguide for conveying the microwaves to the ablation site. The waveguide is sufficiently thin to be inserted into the body and contains a core of dielectric material which enables efficient transmission of microwaves through the waveguide. At the emission end of the waveguide, the dielectric core protrudes and provides a radiating tip for coupling microwaves into surrounding tissue. An object of the inventor is to provide an improved radiator.

According to one aspect, the invention consists in an elongate ~~device~~microwave radiator for insertion into a living body~~, the device having an antenna at its tip for coupling radiation into biological matter and a dielectric body surrounding the antenna so as to encompass substantially the whole of of the near field of the radiation emitted by the antenna~~ to treat biological tissue at a predetermined operating frequency, the radiator comprising a monopole antenna at its tip and dielectric material surrounding the antenna; characterised in that said dielectric material is adapted so that it acts as a resonator at said predetermined operating frequency, and encompasses generally the whole of the near-field radiation emitted by the antenna.

The invention is based on an appreciation of the fact that the antenna generates a near-field, and that the near-field contains large field amplitudes which exist quasi-statically in the local region of the antenna and do not radiate energy. In a normal communications antenna, this local region is air-filled and these near-field amplitudes have no effect except to contribute

reactance to the antenna impedance. However, in a medical application, if the near-field region contains biological matter, which is highly lossy, the near-field amplitudes will generate heat.

Because of the high amplitudes and small volume of the near-field region, much heat can be generated in the near-field region, which reduces the energy in the far-field. Field penetration is therefore reduced, and local charring in the near-field region becomes a limiting factor in the power that can be input to the antenna.

The dielectric body according to the invention serves to provide a low loss environment to encompass the near-field region so that more power is transmitted to the biological matter in the far-field region.

The extent of the near-field is determined by the wavelength λ of the radiation in the dielectric and the ~~major dimension~~length L of the antenna according to the relationship $2L^2/\lambda$. ~~Furthermore, in an antenna, L is proportional to λ.~~ The extent of the near-field therefore is proportional to λ, and it is possible to reduce the extent of the near-field region by increasing~~,~~ the dielectric constant of the body to reduce the wavelength of the radiation within it. The overall external dimension of the device can therefore be reduced for insertion into a living body. A higher dielectric constant will also accommodate the use of lower frequency radiation, which would otherwise increase the wavelength and the extent of the near-field; the lower frequency radiation being beneficial in increasing radiation penetration into the far-field.

The antenna is preferably a monopole antenna, which for good impedance matching, has L generally equal to λ/2. By substitution in the above relationship, the extent of the near-field is then equal to λ/2, and this determines the minimum extent of the dielectric material. Furthermore, a λ/2 dimension for the dielectric material is consistent with its operation as a resonator to ensure that the radiator is effective in transmitting radiation at the required power levels for the treatment of biological material.

In one embodiment of the invention, the dielectric body comprises a cylindrical shape with the antenna extending axially along its ~~centre~~center~~ a distance L, with the radius of the cylinder being subtantially equal to 2L²/λ~~. A ~~device~~radiator of this kind can be designed with a minimum radius for insertion into biological matter, such as a liver, and will create an annular radiation field around it. A pointed tip may be provided at the free end of the dielectric material to assist penetration of biological matter.

~~The length L of the antenna may be substantially equal to half a wavelength, in which case the radius of the cylindrical dielectric body is substantially equal to half a wavelength. The antenna is then tuned to act as a resonator, which inreases the power it radiates.~~

~~However, as~~As the dielectric constant is increased, it may exceed that of the biological matter, which can lead to total internal reflection of radiation within the dielectric and a consequent reduction in transmitted radiation. In order to overcome this problem, the dielectric body is formed so that the dielectric constant at its core is higher than that at its outer periphery, the latter having a value intermediate that of the core and the biological matter. Thus, the dielectric constant at the core may be higher than that of the surrounding biological matter so as to help reduce the overall diameter of the ~~device~~radiator. The different dielectric constants may correspond to different layers of dielectric, each with a different dielectric constant, or may correspond to different levels in a dielectric in which the dielectric constant varies throughout its depth.

According to another aspect, the invention consists in an elongate ~~device~~microwave radiator for insertion into a living body~~, the device having an~~ to treat biological tissue at a predetermined operating frequency, the radiator comprising a monopole antenna at its tip ~~for coupling radiation into biological material and a dielectric body~~ and dielectric material surrounding and extending beyond the antenna~~ so as to enhance~~; characterised in that said dielectric material terminates in a rounded tip portion and is adapted so that it acts as a resonator

at said predetermined operating frequency and enhances transmission of radiation in the forward direction.

Preferably,~~ the dielectric body completely envelops the antenna and has a tip portion that extends beyond the end of the antenna to support internal reflection of the radiation in the forward direction. Advantageously, the dielectric body is tuned to act as a resonator to further enhance radiation from the tip of the elongate device in the insertion direction. In particular, the diameter of the dielectric body is substantially equal to the wavelength of the radiation, and~~ the tip portion is ~~substantially~~generally hemispherical and has a radius ~~substantially~~generally equal to half a wavelength of the radiation in the dielectric material.

The ~~elongate device~~ radiator may further comprise a coaxial conductor (preferably packed with a dielectric) which supplies radiation to the antenna from a radiation generator. Preferably, the antenna then comprises an exposed length of the central conductor of the coaxial conductor at its distal end. Preferably, the exposed length of the central conductor providing the antenna, is ~~substantially~~generally half ~~a~~the wavelength ~~long~~of the radiation in the dielectric. The coaxial conductor may be rigid or a flexible cable.

Preferably, the dielectric ~~body~~material has a dielectric constant, or relative permittivity, such that the length of the antenna is reduced. Advantageously, there can be a transformer between the coaxial conductor and the dielectric ~~body~~material to reduce reflection of radiation back into the coaxial conductor from the boundary between it and the dielectric ~~body~~material. Such a transformer can advantageously contain a space into which the dielectric packing of the coaxial conductor can expand.

According to yet another aspect, the invention consists in methods of coupling radiation into biological material using the devices according to the invention.